The Energy Access Co-Pilot for City Governments

Polisense.AI – Methodology Whitepaper
AI x City Climate Action Hackathon 2025 Submission

Executive Summary

Cities are at the forefront of the climate crisis, yet many still struggle with energy poverty and limited visibility on where interventions will have the most impact. **Polisense.AI** proposes an **AI-driven Energy Access Co-pilot for City Governments**, designed to provide actionable insights, prioritize high-impact interventions, and accelerate progress toward **universal, reliable, and sustainable energy access**.

Our methodology integrates diverse datasets, advanced AI models, and transparent prioritization frameworks into a single **decision-support platform**. This allows cities to **track progress, allocate resources efficiently, and engage stakeholders in evidence-based policy making**.

Problem Definition & Objectives

Challenge:
Energy poverty disproportionately affects vulnerable urban communities. Many cities lack the data, tools, and processes to identify, prioritize, and implement interventions effectively.

Objectives:

- Build a **single source of truth** for urban energy access data.
- Prioritize interventions based on **Need, Feasibility, and Impact**.
- Enable cities to make **faster, evidence-based decisions** with transparent justification.

- Provide an **AI co-pilot** that supports planning, communication, and citizen engagement.

Conceptual Framework

The solution is designed around three pillars:

1. **Integrated Data Value Chain**
    - Collect and unify data across population, infrastructure, energy usage, and environmental indicators.
    - Provide transparent, standardized metrics for cross-departmental decision-making.
2. **AI-driven Prioritization Methodology**
    - Apply an evidence-based scoring model to identify areas with the highest potential impact.
    - Enable configurable weighting so cities can align priorities with local policy objectives.
3. **Decision Support & Citizen Engagement**
    - Generate actionable insights for policymakers.
    - Provide transparency and feedback loops to citizens to improve policy alignment.

Solution & System Architecture

Solution Architecture

- **AI Co-Pilot Layer:** Core engine that integrates models, produces rankings, and generates policy insights.

- **Data Value Chain:** Ensures integrity and accessibility of input data across ingestion, processing, storage, and analytics.

- **Communication Interface:** Dashboards, reports, and APIs for cross-departmental use.

System Components

1. **Data Ingestion** – Collect satellite nightlight data, census population data, grid infrastructure maps, renewable energy potential layers.

2. **Processing & Storage** – Normalize, clean, and standardize datasets.

3. **AI/ML Analysis** – Apply prioritization methodology and generate ranked neighborhood targets.

4. **Visualization & Reporting** – Provide dashboards and open evidence for policymakers and communities.

The platform implements a **hybrid architecture** that combines a **custom AI-powered backend** with an **open-source data visualization platform**. This design follows a **microservices architecture pattern**, ensuring clear separation between data ingestion, AI analysis, and user-facing interfaces. The architecture not only supports modular growth but also allows for easy integration with government systems and open data platforms.

High-Level Architecture

The solution comprises two main components:

1. **Custom AI Backend (webApi)** – A TypeScript-based Express.js API server responsible for AI research, data processing, and real-time analytics. Based on Policy Synth.

2. **ResourceWatch Frontend** – A Next.js application for advanced geospatial visualization and interactive policy dashboards.

This separation enables **independent scaling** of backend processing and frontend rendering, optimizing system performance across diverse urban environments.

System Architecture Diagram

The system architecture integrates multiple external data sources into a unified analytical pipeline, processed by advanced AI models and visualized through an interactive user interface.

External Data Sources Include:

- **MAIIA EI BID Informality Data** – Socioeconomic indicators related to informal settlements.
- **EIA Energy Access Data** – Global and regional energy access datasets.
- **NASA Nightlights Data** – High-resolution satellite imagery for energy poverty detection.
- **ClimateTrace Emissions** – Greenhouse gas emissions data to link energy access with climate impacts.

Software Components:

- **Polisense UI** – A responsive, user-friendly interface for policy exploration.
- **Polisense Backend API** – The core engine orchestrating AI-driven insights.
- **AI RAG Module** – Retrieval-Augmented Generation for intelligent, context-aware decision support.
- **Multi-modal AI** – Processing satellite imagery, energy datasets, and policy documents.
- **ResourceWatch Integration** – Leveraging open-source tools for data transparency and visualization.

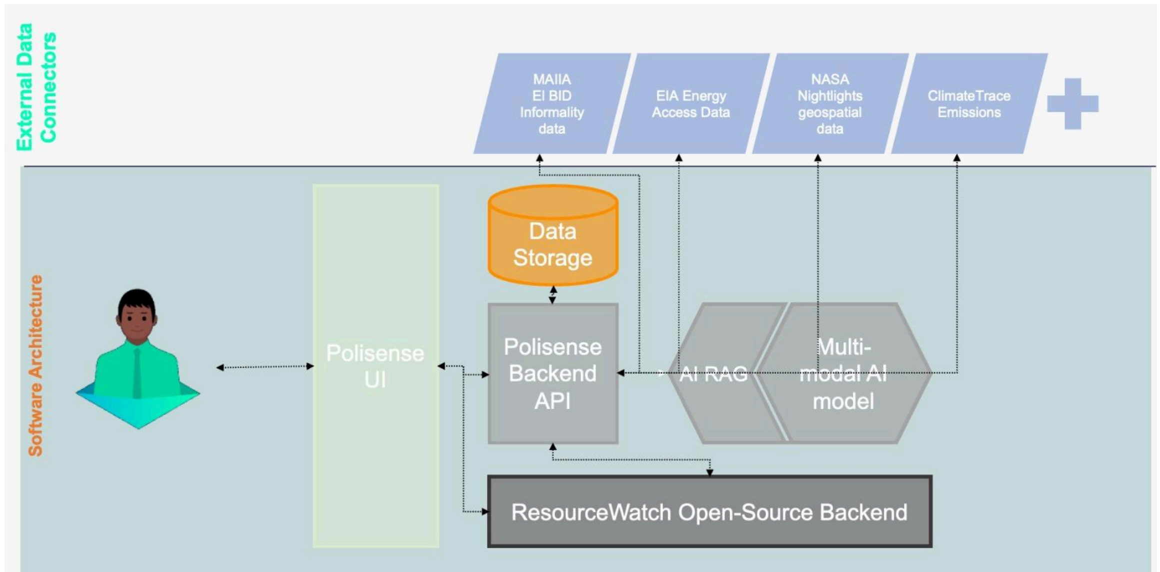

Figure 1: Polisense AI software architecture

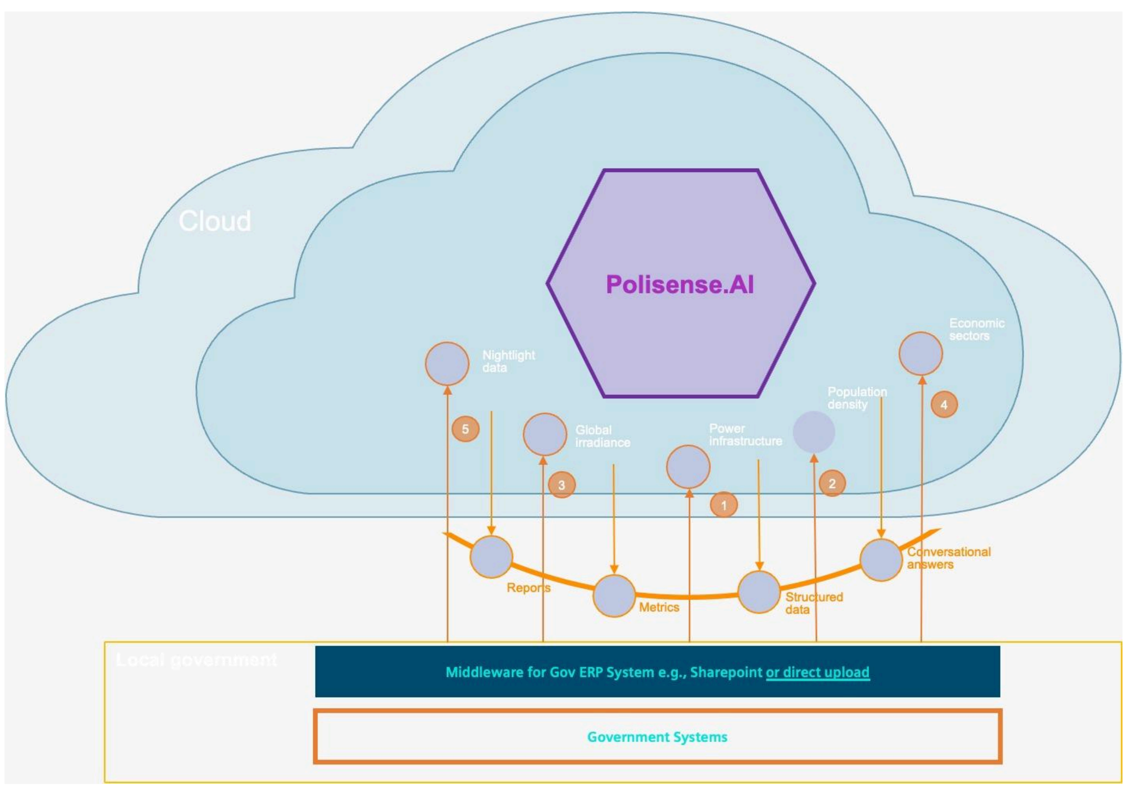

Figure 2: Middleware and cloud system for Polisense AI

Cloud-Based Deployment

Polisense.AI is deployed on a **cloud-native infrastructure** to ensure **scalability, security, and global accessibility**. The cloud-based architecture enables real-time analytics for city governments while maintaining robust data governance.

Key Features of the Deployment:

- Multi-region support for global cities.
- Integration with **government ERP systems** through secure middleware.
- High availability via **Kubernetes orchestration**.
- Scalable storage for large geospatial datasets and AI models.

The system processes data streams from multiple sources, transforms them through AI pipelines, and delivers actionable insights through interactive dashboards and API endpoints.

Backend Architecture (webApi)

The backend serves as the **AI-driven brain of the platform**, managing data ingestion, analysis, and orchestration of research tasks.

Core Technologies:

- **Express.js** – RESTful API framework for backend services.
- **TypeScript** – Ensures maintainability and type safety.
- **PostgreSQL** – Central relational database for structured datasets.
- **Redis** – In-memory caching for real-time performance.
- **Weaviate** – Vector database supporting RAG-based AI functionalities.

AI Research Pipeline Components:

- **SearchQueriesGenerator** – Generates intelligent search queries for research.
- **SearchQueriesRanker** – Uses LLM-based pairwise comparison for ranking.
- **ResearchWeb** – Interfaces with search APIs for data retrieval.
- **SearchResultsRanker** – Scores relevance using GPT-based models.
- **WebPageScanner** – Extracts structured insights from unstructured web content.

Real-Time Processing Features:

- WebSocket-based streaming for **live updates** to city dashboards.
- Continuous token usage monitoring for cost optimization.
- Session persistence via Redis.

Frontend Architecture (ResourceWatch)

The frontend ensures **intuitive interaction with complex data layers**, enabling decision-makers to visualize energy poverty patterns and prioritize interventions effectively.

Key Technologies:

- **Next.js & React** – Modern, fast rendering for dashboards.
- **Redux** – State management for real-time interactivity.
- **Mapbox GL + Deck.gl** – High-performance geospatial visualization.
- **Material-UI & Tailwind CSS** – Consistent, responsive design system.

Core Capabilities:

- Layered visualization of energy access indicators.

- Real-time dashboards integrating AI recommendations.
- Interactive policy simulation tools for scenario testing.
- Widget-based UI for easy customization by city officials.

Data Flow & Integration

The system follows a structured **data pipeline** that ensures integrity and transparency.

Stages:

1. **Data Ingestion** – Aggregates satellite imagery, demographic data, and infrastructure maps.
2. **AI Processing** – Normalizes and scores neighborhoods based on Need, Feasibility, and Impact.
3. **Visualization** – Presents insights via dynamic maps and interactive dashboards.

Integration with External Systems:

- ResourceWatch API for dataset management.
- Google Earth Engine for satellite analysis.
- Secure government ERP middleware for seamless adoption.

Security, Performance & Scalability

Polisense.AI employs **enterprise-grade security practices** and **performance optimizations** to support large-scale deployments.

Security Features:

- API key authentication and role-based access control.

- Comprehensive **CORS** and **input validation** mechanisms.
- Secure environment variable management.

Performance Optimizations:

- Redis caching for frequent queries.
- Load balancing and **horizontal scaling** through Kubernetes.
- Code-splitting and lazy loading for optimized frontend performance.

Scalability Considerations:

- Agent pool management for AI tasks.
- Distributed data storage for high-volume datasets.
- Event-driven architecture for real-time alerts.

Methodology: Prioritizing Areas for Energy Access

The methodology evaluates **Need, Feasibility, and Impact** using measurable indicators.

Indicators:

- **Need:** Population density > 5,000 people/km^2, Night-lights < 50 lux per capita, Household energy spend > 10% of income, Grid access < 50% of households.
- **Feasibility:** Distance to grid < 2 km, Infrastructure coverage > 50%, Presence of formal addresses, Security score > 0.7 (0–1 scale).
- **Impact:** Potential to reach > 500 households, Solar PV potential > 100 kWh/m^2/year, Co-benefits: reduced indoor pollution, improved air quality.

Scoring Formula:

accessPriority = w_1 × normalize(Need) + w_2 × normalize(Feasibility) + w_3 × normalize(Impact)

(Default weights: $w_1 = 0.5$, $w_2 = 0.3$, $w_3 = 0.2$)

Use Cases & User Workflow

Workflow

1. **Data Collection**
   Gather satellite, infrastructure, and socioeconomic datasets to provide a comprehensive view of urban energy needs.

2. **Request & Analysis**
   City officials request a prioritized list of areas for intervention, ensuring data-driven decisions.

3. **AI Processing**
   The AI co-pilot applies a scoring methodology to generate actionable recommendations for targeted energy access initiatives.

4. **Policy Review & Engagement**

   - AI reviews current policies to identify gaps and opportunities.
   - Officials refine policies and collaborate across departments to ensure alignment.
   - Citizen feedback loops enhance accountability, transparency, and trust in decision-making.

Use Cases

- Expansion of last-mile energy access to underserved communities.
- Targeted solar PV deployment for optimized energy coverage.
- Transparent reporting of investment impacts to stakeholders.
- AI-assisted policy review and iterative improvements for continuous learning.

Features

- **Integrated AI Energy Access Co-pilot** – Provides unified insights and serves as a single source of truth for energy access planning.
- **Efficient Decision-Making** – Enables rapid reporting and fosters cross-department communication.
- **Transparent & Analytical** – Offers explainable AI, evidence-based prioritization, and open access for city stakeholders.

Future Enhancements

Planned improvements include:

- **Full microservices migration** for modular scalability.
- **Event-driven architecture** for real-time updates.
- **Edge computing capabilities** for local data processing.
- **Citizen engagement platforms** for participatory policy-making.

These advancements will ensure that Polisense.AI remains a **future-ready solution for urban energy access and climate resilience**.

Strategy & Outlook

- **Pilots** – Launch initial projects in Latin American cities, such as Arequipa, Peru, to validate methodology.
- **Funding & Partnerships** – Utilize Hackathon mentorship and seed funding to secure pilot partnerships.

- **Scaling** – Expand the scope from energy access to clean cooking and broader climate actions.
- **Long-Term Impact** – Empower cities to achieve measurable progress on SDG 7 (Affordable & Clean Energy) and enhance climate resilience.

Conclusion

Polisense.AI equips cities with an AI-powered methodology to prioritize energy access interventions with **speed, transparency, and measurable impact**. By aligning **data-driven insights** with **policy needs and citizen engagement**, the Energy Access Co-pilot strengthens cities' capacity to deliver reliable, affordable, and sustainable energy for all.

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